Media Contact:
A. Sarah Hreha
1 (203) 432-6231
info@gruber.yale.edu
Online Newsroom: www.gruber.yale.edu/news-media

Mukhanov and Starobinsky to Receive $500,000 Gruber Cosmology Prize for Developing Theory of Universe's Earliest Moments

July 11, 2013, New Haven, CT - The 2013 Gruber Cosmology Prize recognizes Viatcheslav Mukhanov and Alexei Starobinsky for their formative contributions to inflationary theory, an essential component for understanding the evolution and structure of the universe.

Viatcheslav Mukhanov

Alexei Starobinsky

According to the Prize citation, their theoretical work "changed our views on the origin of our universe and on the mechanism of its formation of structure." Thanks to their contributions, scientists have provided a compelling solution to two of the essential questions of cosmology: Why is the structure of the universe so uniform on the largest scales? Where did the departures from uniformity—such as galaxies, planets, and people—come from?

Mukhanov, full professor of physics at the Ludwig-Maximilians-Universität in Munich, and Starobinsky, the main research scientist at the Landau Institute for Theoretical Physics in Moscow, will share the $500,000 award, which will be presented on September 3 as part of the COSMO2013 conference at the Stephen Hawking Centre for Theoretical Cosmology in Cambridge, UK.

The work for which they are being honored began in the late 1970s and early 1980s, during a period of fertile, even fervid, theoretical investigations into the earliest moments of the universe. In 1965 astronomers had discovered the cosmic microwave background—relic radiation dating to an era 13.8 billion years ago, when the universe was approximately 380,000 years old, during which hydrogen atoms and photons (packets of light) decoupled, causing a kind of "flashbulb" image that pervades the universe to this day. This discovery validated a key prediction of the Big Bang theory and inspired a generation of theorists.

Among them was Starobinsky, then a senior research scientist at the Landau Institute. His approach was to use quantum mechanics and general relativity to try to address how an expanding universe might

have originated. While he did not resolve that issue, his calculations made in 1979 - 1980 did indicate that the universe could have gone through an extraordinarily rapid exponential expansion in the first moments of its existence.

The following year Mukhanov (Moscow Physical-Technical Institute) and G. V. Chibisov (Lebedev Physical Institute, Moscow; he passed away several years ago), began working on the implications of quantum fluctuations within the Starobinsky model. Quantum fluctuations—disturbances in the fabric of space predicted by Heisenberg's uncertainty principle—are always present in the universe. But in an extremely small, extremely dense, and extremely energetic newborn universe they would have had an outsized presence. What's more, the kind of exponential expansion that Starobinsky was proposing would have stretched those fluctuations beyond the quantum scale. In 1981 Mukhanov and Chibisov discovered that these fluctuations could play the role of the seeds that eventually bloomed into the present large-scale web-like structure of the universe: galaxies, clusters of galaxies, and superclusters of galaxies.

When this mechanism was first proposed, it looked like a piece of science fiction. Indeed, usually quantum fluctuations appear only on tiny subatomic scales, so the idea that galaxies have been born from quantum fluctuations seemed totally outlandish. And yet the subsequent developments in theoretical and observational cosmology strongly favored this possibility.

Shortly after the Starobinsky work, the American physicist Alan Guth proposed a brilliant idea that an exponential expansion stage of the early universe, which he called "inflation," could explain the incredible uniformity of our universe and resolve many other outstanding problems of the Big Bang cosmology. However, Guth immediately recognized that his proposal had a flaw: the world described by his scenario would become either empty or very non-uniform at the end of inflation. This problem was solved by Andrei Linde, who introduced several major modifications of inflationary theory, such as "new inflation" (later also developed by Albrecht and Steinhardt), "chaotic inflation", and "eternal chaotic inflation." A new cosmological paradigm was born. In 2004, Guth and Linde received the Gruber Prize for the development of inflationary theory.

The original goals of the Starobinsky model were quite different from the goals of inflationary theory. Instead of trying to explain the uniformity of the universe, he assumed that the universe was absolutely homogeneous from the very beginning. However, it was soon realized that the mathematical structure of his model was very similar to that of new inflation, and therefore it naturally merged into the rapidly growing field of inflationary cosmology.

In 1982, several scientists, including Starobinsky, outlined a theory of quantum fluctuations generated in new inflation. This theory was very similar to the theory developed by Mukhanov and Chibisov in the context of the Starobinsky model. Investigation of inflationary fluctuations culminated in 1985in work by Mukhanov, who developed a rigorous theory of these fluctuations applicable to a broad class of inflationary models, including new and chaotic inflation.

This theory predicted that inflationary perturbations have nearly equal amplitude on all length scales. An equally important conclusion was that this scale invariance is close, but not exact: the amplitude of the fluctuations should slightly grow with the distance. These fluctuations would have equal amplitudes for all forms of matter and energy (called adiabatic fluctuations). The theory also predicted a specific statistical form of the fluctuations, known as Gaussian statistics.

Since then, increasingly precise observations of the cosmic microwave background radiation (CMB) have

provided decisive matches for theoretical predictions of how those initial quantum fluctuations would look after the universe had been expanding for 380,000 years. Those observations include all-sky maps produced by the Cosmic Microwave Background Explorer (COBE), the Wilkinson Microwave Anisotropy Probe (WMAP), and the Planck satellite. John Mather and the COBE team received the Gruber Cosmology Prize in 2006; Charles Bennett and the WMAP team received theirs in 2012.

Back in 1979, Starobinsky also found that exponential expansion of the universe should produce gravitational waves — a quantum by-product of general relativity, and a target for the new generation of instruments expected over the next decade.

This year's Gruber Cosmology Prize citation credits Starobinsky and Mukhanov with a profound contribution to inflationary cosmology and the theory of the inflationary perturbations of the metric of space-time. This theory, explaining the quantum origin of the structure of our universe, is one of the most spectacular manifestations of the laws of quantum mechanics on cosmologically large scales.

Additional Information

In addition to the cash award, each recipient will receive a gold laureate pin and a citation that reads:

The Gruber Foundation proudly presents the 2013 Cosmology Prize to Viatcheslav Mukhanov and Alexei Starobinsky for their profound contribution to inflationary cosmology and the theory of inflationary perturbations of the metric. These developments changed our views on the origin of our universe and on the mechanism of formation of its structure.

* * *

Laureates of the Gruber Cosmology Prize:

- **2012: Charles Bennett and the WMAP Team** for their exquisite measurements of anisotropies in the relic radiation from the Big Bang---the Cosmic Microwave Background.
- **2011: Marc Davis, George Efstathiou, Carlos Frenk** and **Simon White** for their pioneering use of numerical simulations to model and interpret the large-scale distribution of matter in the Universe
- **2010: Charles Steidel** for his groundbreaking studies of the distant Universe
- **2009: Wendy Freedman, Robert Kennicutt** and **Jeremy Mould** for the definitive measurement of the rate of expansion of the universe, Hubble's Constant
- **2008: J. Richard Bond** for his pioneering contributions to our understanding of the development of structures in the universe
- **2007: Saul Perlmutter** and **Brian Schmidt** and their teams: the **Supernova Cosmology Project** and the **High-z Supernova Search Team,** for independently discovering that the expansion of the universe is accelerating
- **2006: John Mather** and the **Cosmic Background Explorer (COBE) Team** for studies confirming that our universe was born in a hot Big Bang
- **2005: James E. Gunn** for leading the design of a silicon-based camera for the Hubble Space Telescope and developing the original concept for the Sloan Digital Sky Survey
- **2004: Alan Guth** and **Andrei Linde** for their roles in developing and refining the theory of cosmic inflation

- **2003: Rashid Alievich Sunyaev** for his pioneering work on the nature of the cosmic microwave background and its interaction with intervening matter
- **2002: Vera Rubin** for discovering that much of the universe is unseen black matter, through her studies of the rotation of spiral galaxies
- **2001: Martin Rees** for his extraordinary intuition in unraveling the complexities of the universe
- **2000: Allan R. Sandage** and **Phillip J. E. (Jim) Peebles**: Sandage for pursuing the true values of the Hubble constant, the deceleration parameter and the age of the universe; Peebles for advancing our understanding of how energy and matter formed the rich patterns of galaxies observed today

The Prize recipients are chosen by the Cosmology Selection Advisory Board. Its members are:

Andrew Fabian, University of Cambridge; **Wendy Freedman,** The Observatories of the Carnegie Institution of Washington (Chair); **Gerhard Huisken,** Max Planck Institute for Gravitational Physics; **Helge Kraghe,** Aarhus University; **Andrei Linde,** Stanford University; **Julio F. Navarro,** University of Victoria and **Sadanori Okamura,** Hosei University. **Owen Gingerich** of the Harvard-Smithsonian Center for Astrophysics and **Martin Rees** of the University of Cambridge also serve as special Cosmology advisors to the Foundation.

* * *

By agreement made in the spring of 2011 The Gruber Foundation has now been established at Yale University.

The Gruber International Prize Program honors individuals in the fields of Cosmology, Genetics and Neuroscience, whose groundbreaking work provides new models that inspire and enable fundamental shifts in knowledge and culture. The Selection Advisory Boards choose individuals whose contributions in their respective fields advance our knowledge and potentially have a profound impact on our lives.

The Cosmology Prize honors a leading cosmologist, astronomer, astrophysicist or scientific philosopher for theoretical, analytical, conceptual or observational discoveries leading to fundamental advances in our understanding of the universe.

* * *

Affiliation with International Astronomical Union

In 2000, The Foundation and the International Astronomical Union (IAU) announced an agreement by which the IAU provides its expertise and contacts with professional astronomers worldwide for the nomination and selection of Cosmology Prize winners. Under the agreement, The Gruber Foundation also funds a fellowship program for young astronomers, with the aim of promoting the continued recruitment of new talent into the field.

The IAU is an international astronomical organization of more than 10,000 professional astronomers from more than 90 countries. Its mission is to promote and safeguard the science of astronomy in all its aspects through international cooperation. The IAU also serves as the internationally recognized authority for assigning designations to celestial bodies and surface features on them.

* * *

For more information on the Gruber Prizes, visit www.gruber.yale.edu , e-mail info@gruber.yale.edu or contact A. Sarah Hreha at +1 (203) 432-6231. By mail: The Gruber Foundation, Yale University, Office of Development, PO Box 2038, New Haven, CT 06521.

Media materials and additional background information on the Gruber Prizes can be found at our online newsroom: http://gruber.yale.edu/news-media